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METALS TECHNOLOGY LABORATORIES
REPORT: MTL 89-76(TR)

STUDY OF THE AUSTENITE TRANSFORMATION KINETICS OF TWO MICROALLOYED STEELS FOR SEAMLESS TUBULAR PRODUCT

by

B. Voyzelle, L. Collins and C. Marchand

SUMMARY

As part of a co-operative research agreement with the Algoma Steel Corporation, dilatometer trials were carried out on two compositions of microalloyed steel for seamless tube to produce the continuous cooling transformation (CCT) diagrams. The microstructures and hardnesses of the transformed specimens are included in this report. A discussion of experimental results is added to provide a complete study of the austenite transformation kinetics on cooling for these microalloyed steels.

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ÉTUDE DE LA CINÉTIQUE DE TRANSFOMATION DE L'AUSTÉNITE DE DEUX ACIERS MICRO-ALLIÉS UTILISÉS COMME PRODUIT TUBULAIRE SAND SOUDURE

par

B. Voyzelle, L. Collins et C. Marchand

SOMMAIRE

Dans le cadre d'une entente de recherche en commun avec l'Algoma Steel Corporation, des diagrammes de transformation en refroidissement continu de deux compositions d'acier ont été obtenus par des essais en dilatométrie. Ces deux compositions appartiennent à la classe des aciers micro-alliés à tube sans soudure. Les microstructures et les valeurs de dureté des échantillons transformés sont incluses dans ce rapport. Une discussion des résultats expérimentaux est ajoutée afin de compléter l'étude de la cinétique de transformation au refroidissement de l'austénite pour ces aciers micro-alliés.

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14 pp

MICROMEDIA

INTRODUCTION

As part of a co-operative research agreement with the Algoma Steel Corporation, dilatometer trials were carried out to generate continuous cooling transformation (CCT) diagrams for two grades of steel. These steels were identified by CANMET as 2998C and 3032A and were described as microalloyed steel for seamless tubular product.

Dilatometry was used to determine the CCT diagrams. In addition to the dilatometer tests, metallographic examination and hardness testing were done to verify the interpretation of data, and express hardness results in the form of generalized hardenability diagrams. Preliminary CCT diagrams were forwarded to Mr. P. Hunt, Senior Research Associate, Algoma Steel Corporation, on August 11, 1989. This report describes the experimental procedures and presents a complete summary of the results.

EXPERIMENTAL

An MMC dilatometer was used for this study and its operation is described in Ref. 1.

Dilatometer specimens 8 mm in length and 4 mm in diameter were machined from ingot steel cast in the MTL Foundry. The chemical analyses of the alloys, are shown in Table 1.

The specimens were heated to the austenitizing temperature of 1150°C in 2 min and held 15 min at this temperature, followed by two steps of deformation, 37.5% at 950°C and 50% at 825°C, prior to cooling at rates between 150 and 0.3°C/s. Newtonian cooling was employed and the average cooling rate (R) was evaluated between 800 and 500°C. Ac_1 and Ac_3 temperatures were determined at a constant heating rate of 2°C/min.

Each CCT diagram (Figs. 1 and 2) presents the data in such a way that start and finish temperatures of phase transformations, isotransformation contours (10, 50 and 90%) and individual cooling curves are shown on a plot of temperature versus logarithm of time. These data were obtained by using standard techniques explained in Ref. 2. Also included on each diagram are the Ac_1 and Ac_3 temperatures, hardness of the as-cooled dilatometer specimens and the cooling rate (R) at the end of each cooling curve. Hardenability is presented in Fig. 3 in terms of Vickers hardness (10 kg load) versus half-cooling time which is defined as the time to reach the temperature midway between Ac_3 and room temperature (25°C).

RESULTS AND DISCUSSION

Steels 2998C and 3032A have similar chemical compositions except that C content is higher in 3032A steel. This difference is essentially to obtain a higher yield strength for steel 3032A. The CCT and hardenability diagrams of steels 2998C and 3032A are presented in Figs. 1

to 3, respectively. The microstructure of cross-sections of the as-cooled specimens of both steels are shown in Figs. 4 and 5.

A fully martensitic structure was observed only in steel 3032A at a cooling rate of 150°C/s, with an M_s temperature of 375°C. The M_s temperature for steel 2998C is 390°C. The onset of diffusional transformation occurs at a cooling rate between 150 and 34°C/s for steel 3032A and at cooling rates greater than 111°C/s for steel 2998C.

The transformation of austenite to ferrite occurs more rapidly in steel 2998C than in steel 3032A. The maximum B_s temperature of both microalloyed steels is considered similar. However, the bainite zone of the 3032A steel is wider than that of steel 2998C. Total ferrite-pearlite structure was obtained at cooling rates lower than 1°C/s and 0.3°C/s for steels 2998C and 3032A, respectively. Figure 3 shows that the hardenability of steel 3032A is superior to that of steel 2998C. As it is well known that harder steel has a higher yield strength, then steel 3032A should have a higher yield strength than steel 2998C. This is consistent with the expected effect of higher C content.

At the request of the Algoma representative, the austenite fraction transformed for cooling rates of 3 and 1°C/s in steel 3032A is shown in Fig. 6. It is noted that the fraction transformed in the ferrite-pearlite phase (730-530°C) is less for the cooling rate of 3°C/s than that of 1°C/s. This allows a larger amount of bainite in the resulting microstructure.

CONCLUSIONS

The CCT diagrams, hardenability curves and corresponding microstructures were produced for two compositions of microalloyed steel seamless tube. Differences between CCT diagrams were noted and the superior hardenability of steel 3032A was related to the C content.

ACKNOWLEDGEMENTS

This work was carried out as part of a cooperative research project with the Algoma Steel Corporation Ltd. on pilot scale simulation of microalloyed steel seamless tube.

REFERENCES

1. Collins, L.E., Barry, J.R., "Operations of the MMC quench-deformation dilatometer", CANMET Division Report PMRL 84-28(TR); April 1984.

2. Eldis, G.T., "Hardenability concepts with applications to steel", Ed. D.V. Doane and J.S. Kirkaldy, AIME, 126-157; 1978.

Table 1. Chemical analysis of microalloyed steel for seamless tube (wt %).

	Steel	
Element	2998C	3032A
C	0.12	0.19
Mn	1.7	1.7
Si	0.37	0.36
P	0.014	0.014
S	0.008	0.008
Al	0.019	0.027
Ti	0.013	0.012
V	0.16	0.15
N	0.0200	0.0185

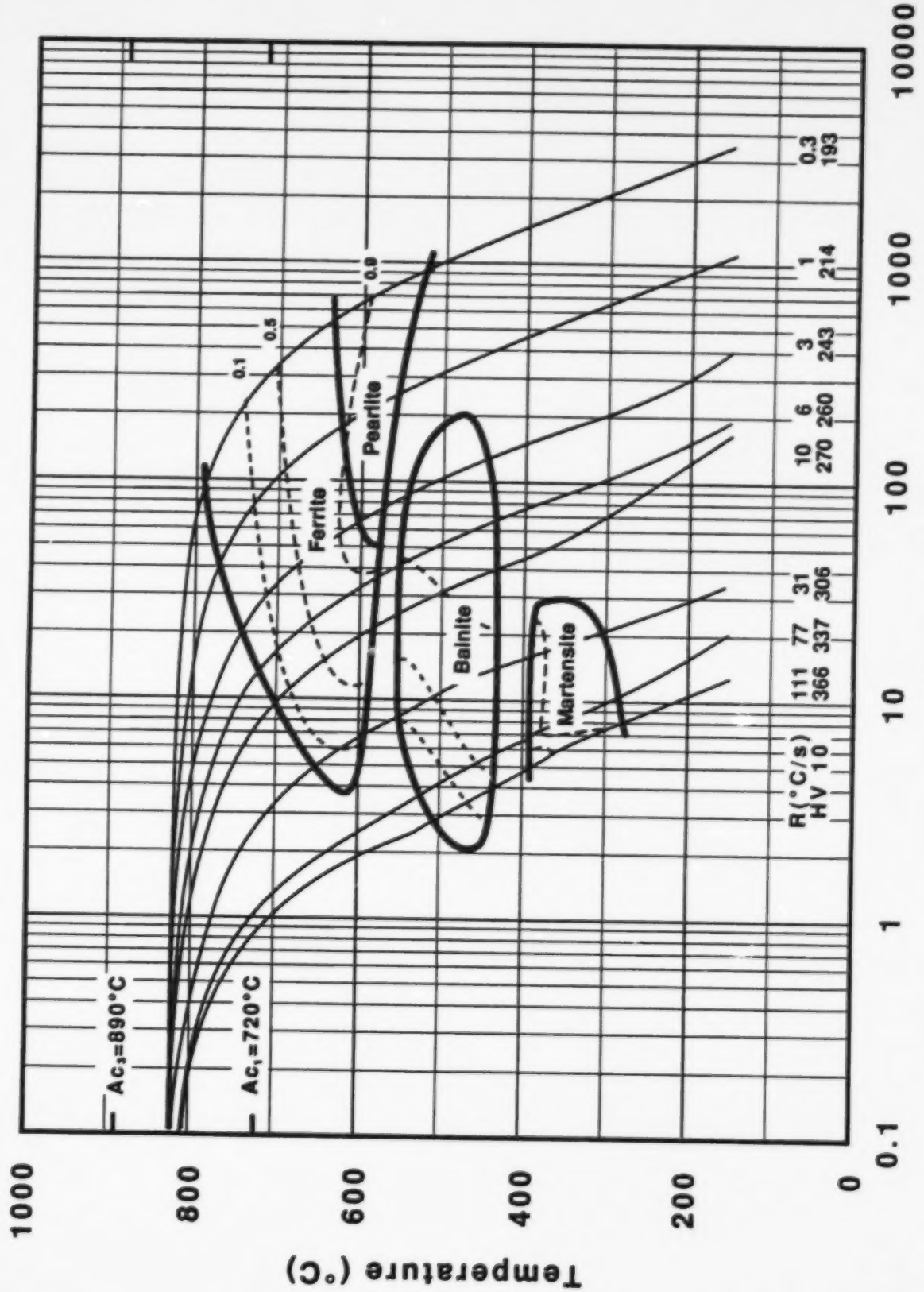


Figure 1 - CCT diagram of steel 2998C.

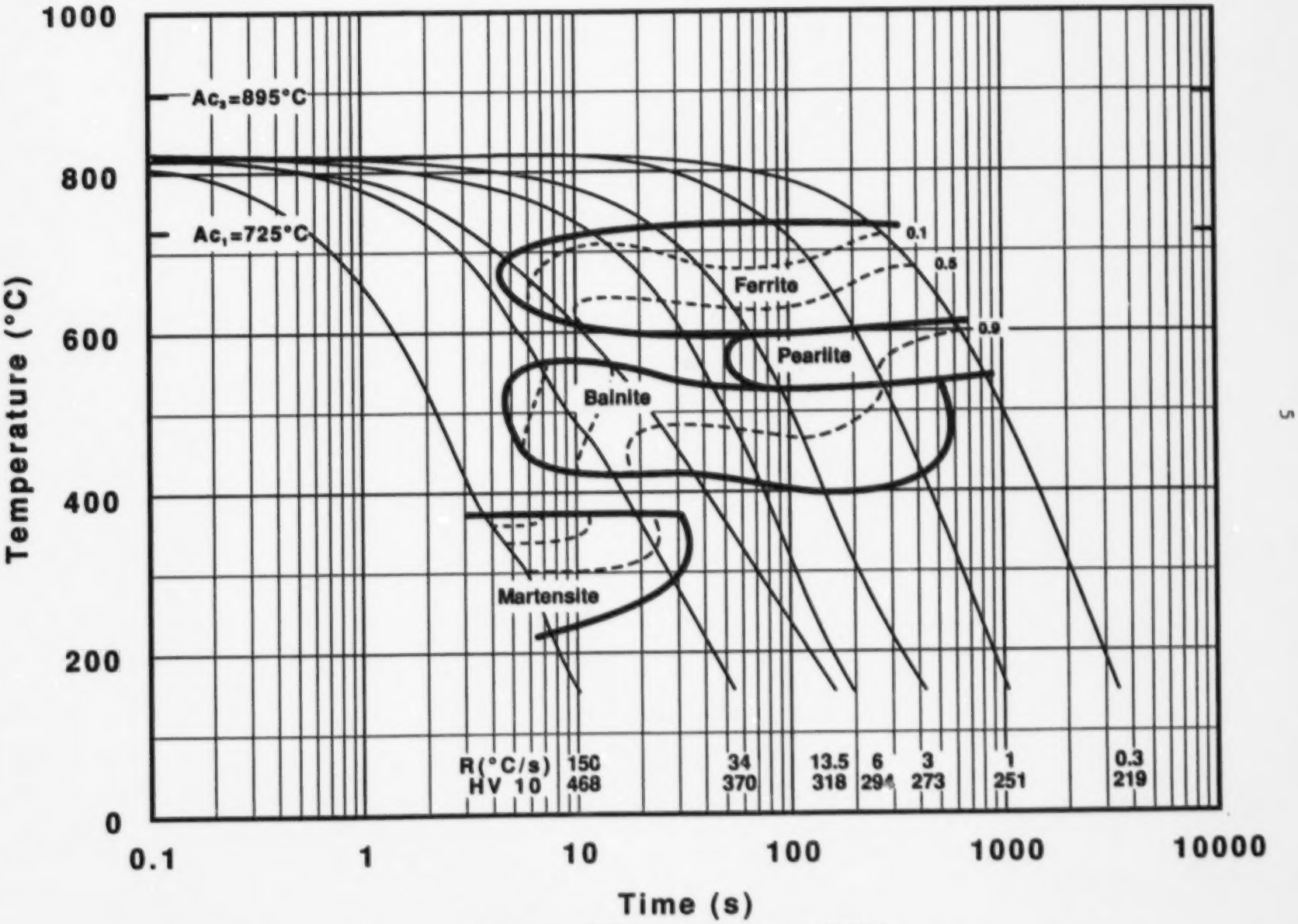


Figure 2 - CCT diagram of steel 3032A.

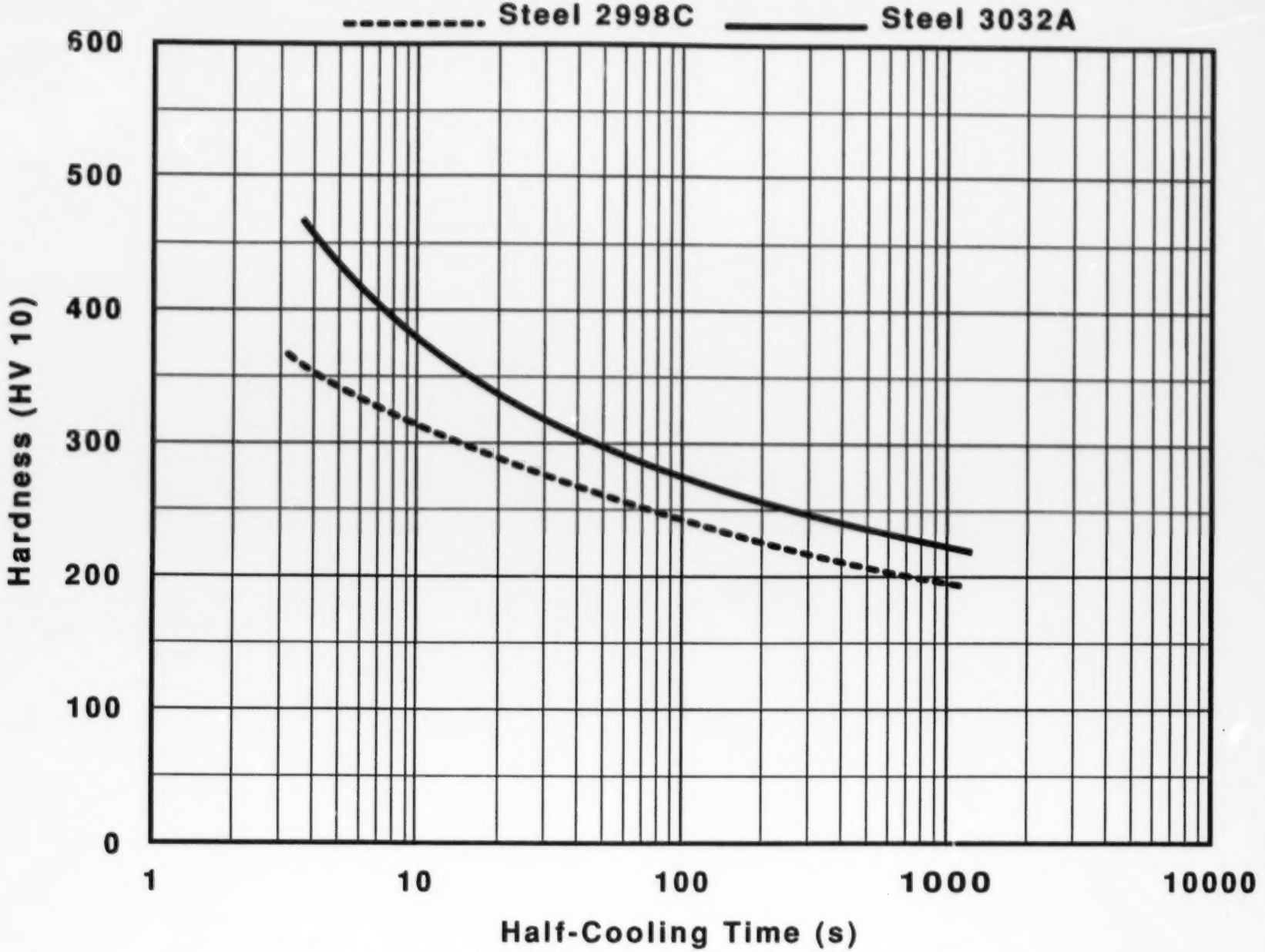
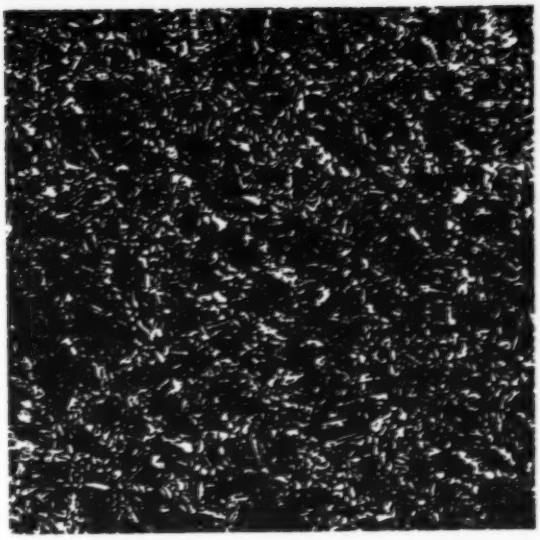
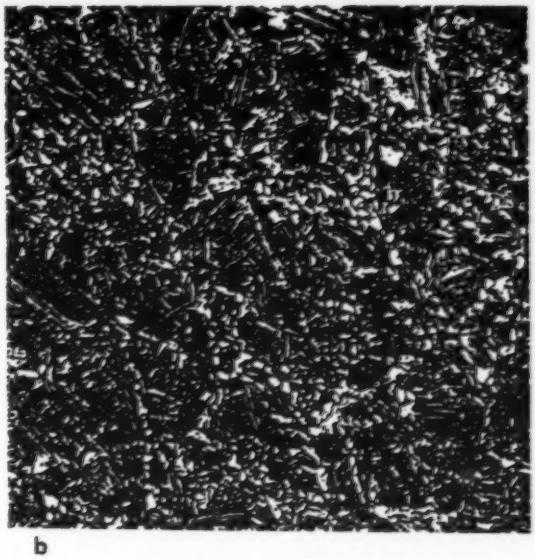


Figure 3 - Hardenability diagram of microalloyed seamless tubular steels.



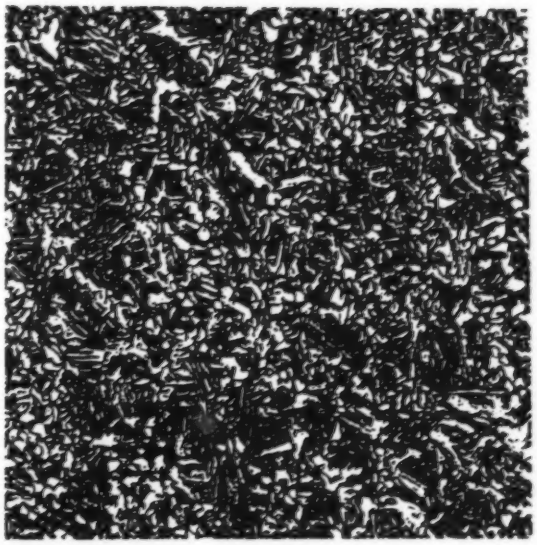
a

111°C/s
366 HV 10



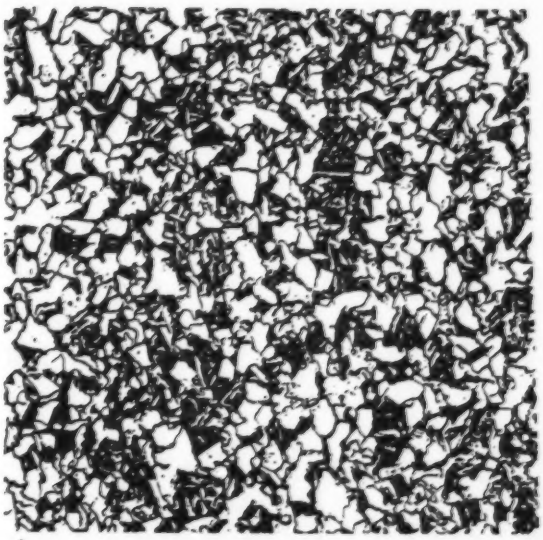
b

77°C/s
337 HV 10



c

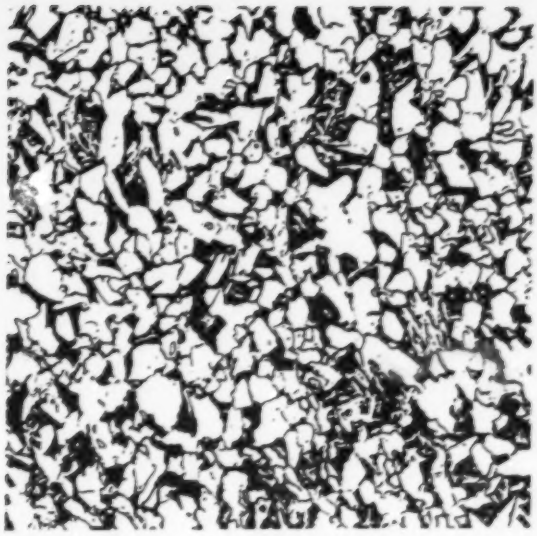
31°C/s
306 HV 10



d

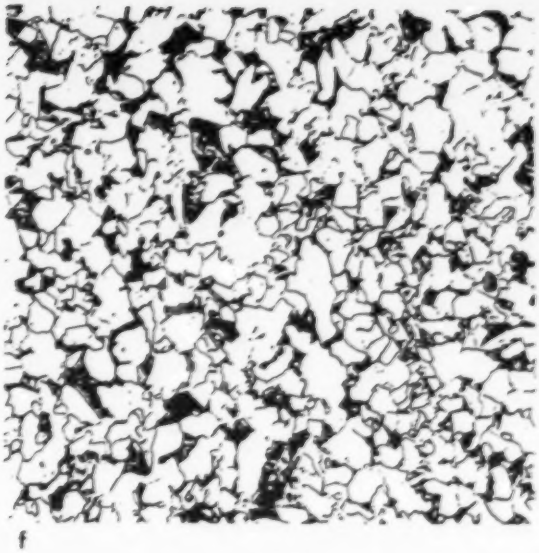
10°C/s
270 HV 10

Figure 4 - Microstructures of steel 2998C after cooling at various rates (500x).



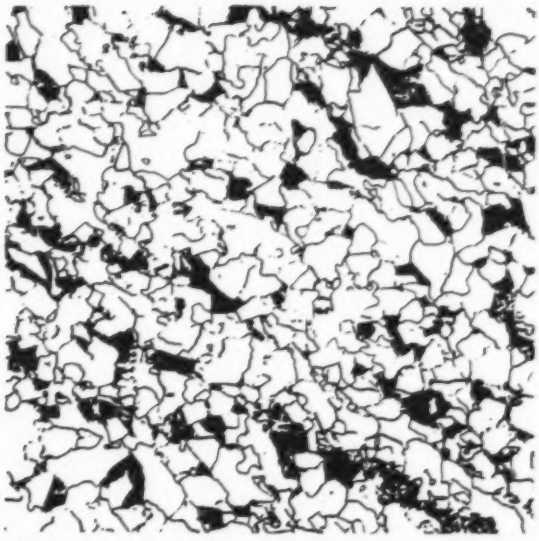
e

6°C/s
260 HV 10



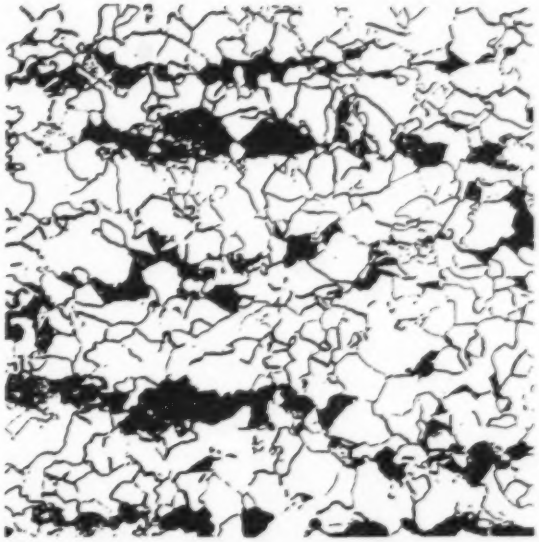
f

3°C/s
243 HV 10



g

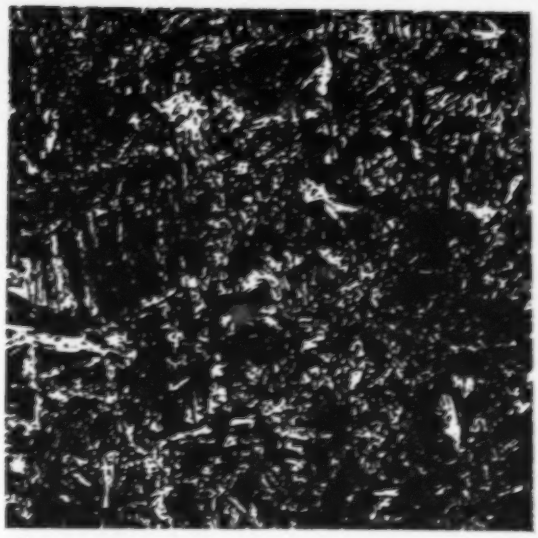
1°C/s
214 HV 10



h

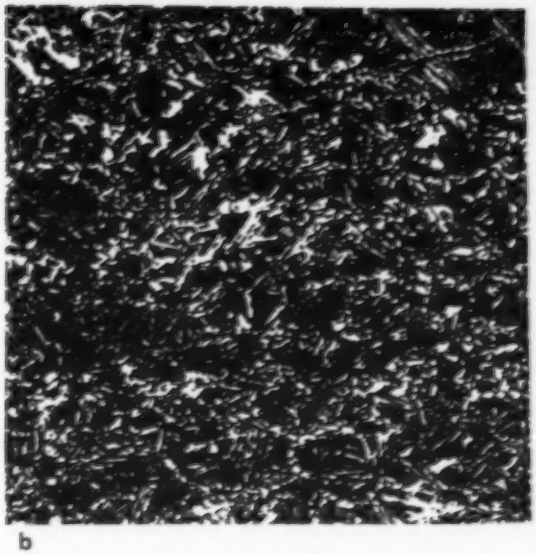
0.3°C/s
193 HV 10

Figure 4 - Microstructures of steel 2998C after cooling at various rates (continued).



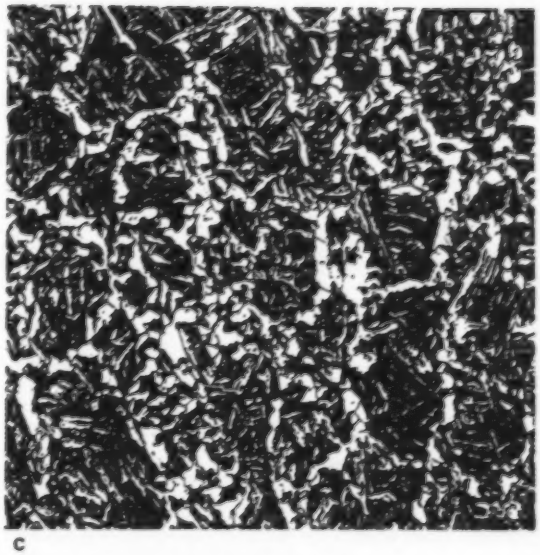
a

150°C/s
468 HV 10



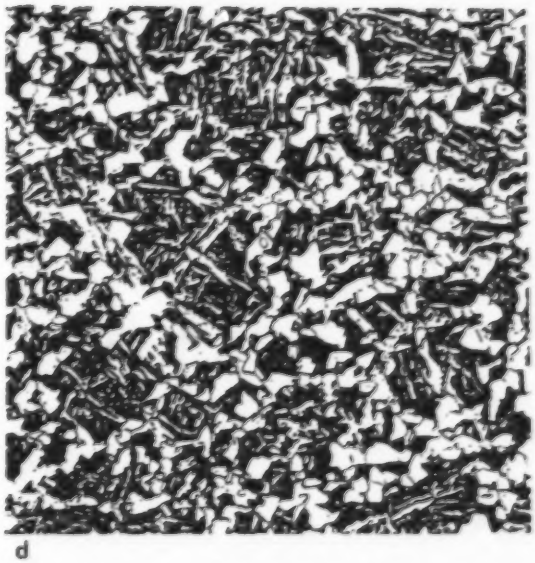
b

34°C/s
370 HV 10



c

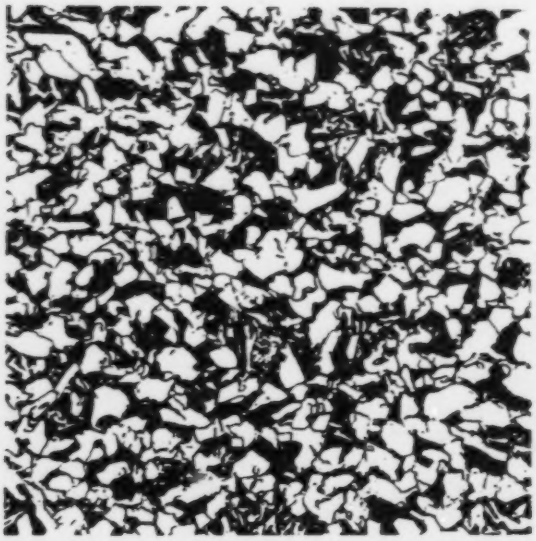
13.5°C/s
318 HV 10



d

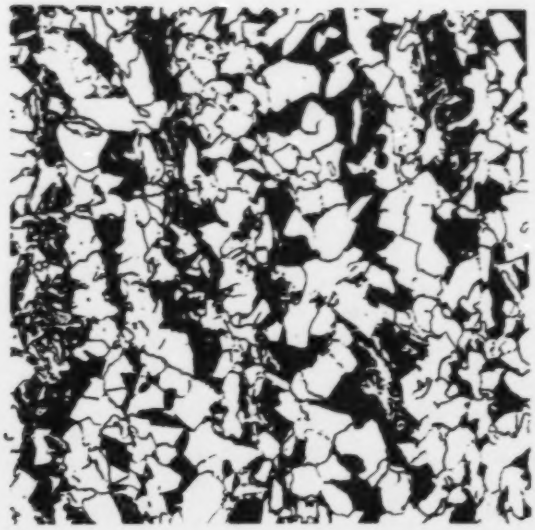
6°C/s
294 HV 10

Figure 5 - Microstructures of steel 3032A after cooling at various rates (500x).



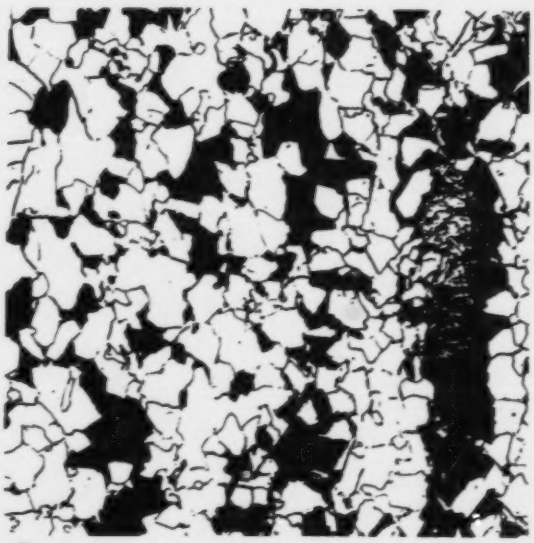
e

3°C/s
273 HV 10



f

1°C/s
251 HV 10



g

0.3°C/s
219 HV 10

Figure 5 - Microstructures of steel 3032A after cooling at various rates (continued).

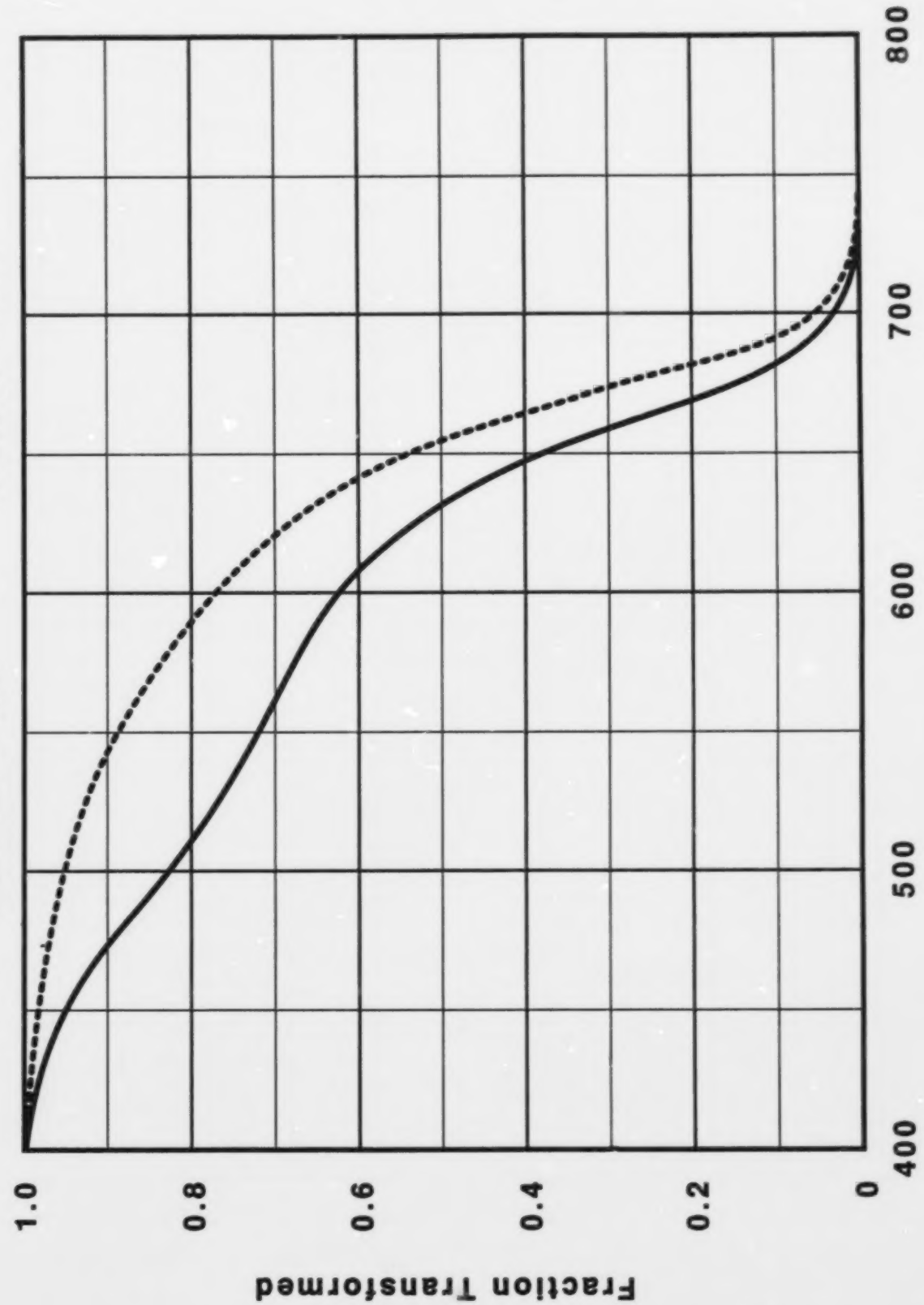


Figure 6 - Austenite fraction transformed for some cooling rates of steel 3032A.

Fig. 4(a) --- Neg 19881
Fig. 4(b) --- Neg 19882
Fig. 4(c) --- Neg 19883
Fig. 4(d) --- Neg 19884
Fig. 4(e) --- Neg 19885
Fig. 4(f) --- Neg 19886
Fig. 4(g) --- Neg 19887
Fig. 4(h) --- Neg 19888

Fig. 5(a) --- Neg 19889
Fig. 5(b) --- Neg 19890
Fig. 5(c) --- Neg 19891
Fig. 5(d) --- Neg 19892
Fig. 5(e) --- Neg 19893
Fig. 5(f) --- Neg 19894
Fig. 5(g) --- Neg 19895